

THE VOLCANOES OF GRIQUALAND EAST.

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The Drakensberg Mountains have for a very long while been known to be of volcanic origin ; the amygdaloid with which they are capped is easily recognised to be an undoubted volcanic lava which has been poured out on the surface of the earth, as opposed to a trap rock, in this country principally dolerite, which has been injected into the strata without any vent whereby it could come to the surface. Four years ago Mr. Churchill contributed a paper to this Society on the amygdaloids of the Drakensberg Mountains in Natal, and many other writers have also called attention to the character of the rocks which form this range.

In 1878 Mr. E. J. Dunn made a detailed survey of the country round Molteno and Jamestown, which lie at the western end of the Drakensberg range, and in the map accompanying the report he shows three centres of eruption, two near Molteno and one near Jamestown. In an unpublished map by him of the country east of Jamestown he shows two more centres of eruption. Although he described these volcanic pipes with accuracy, and saw the bearing the discovery of them had on the elucidation of the geology of this region, the fact seems to have been generally overlooked, and no further volcanoes had been discovered till the geological survey party recently found some nineteen or twenty well-marked vents in Matatiele. Mr. Dunn lays stress in his report on the similarity of these vents with the diamondiferous pipes of Kimberley and the west of the colony, but in spite of the similarity of the structure, both being large vertical pipes piercing the strata and filled in with ejected material which has fallen back and clogged up the hole, yet

there is a great diversity in the character of the agglomerate or mixed-up material in the pipes. In the diamondiferous pipes, and similar ones in the west, and also in the Bingara diamond pipe in New South Wales, the agglomerate consists principally of the *débris* of very basic rocks, which are not known to occur *in situ* in South Africa, whereas the volcanic pipes of Griqualand East are filled in with material usually with a very high percentage of silica.

One fact makes the Griqualand East volcanoes of special interest. They are very old, belonging to the upper Jurassic or Cretaceous periods. Old volcanoes like these are known from many parts of the world, and many midway in age between these and recent ones; but in these foreign ones either all traces of surface features are entirely swept away by the long-continued action of wind and weather, and we have only a hardly recognisable stump remaining; or, like in the Eifel, the whole cone is covered in by sediments and the surface features are preserved while the internal structure is hidden. In Matatiele, however, we get these stumps, and can see the condition of things in the pipe many thousands of feet below what was once the orifice of the volcano, but we can also trace some of the surface features as well, and in one instance one can actually see the lava still in continuity with the mass of molten material in the pipe, pouring out over the surface of the old land-surface, and can trace the ropy surface which the viscid liquid acquired as it cooled, in days when the highest living being was a reptile. In this way one has, by piecing together the evidence from two or three closely adjoining vents, a natural section of a volcano of 4,000 or 5,000 feet in vertical extent.

A volcano either pours out liquid lava or throws out dust and ashes, or does both alternately. Among the Matatiele volcanoes one can find all three varieties; that is to say, some of the vents are filled almost entirely with solidified lavas, forming immense plugs; others are cylinders of dust and ashes, long consolidated into compact rock, while other pipes again are filled in with varying proportions of both. Of course one and the same volcano under different circumstances may play both parts at different times; a volcano may for centuries continue to quietly pour out lava, and then of a sudden enter on an explosive stage. From the fact that all the Matatiele pipes, with one possible exception, contain some ash or agglomerate, it is highly probable that the last stage of the volcanoes was an explosive one, whatever kind of activity they previously had.

It will be noticed that all these vents discovered in Matatiele occur south of the Drakensberg range, and at first sight it would seem that these volcanoes confined their attention to the northern side,

leaving the country on the southern side of the vent uncovered, but it is easily seen how this state of affairs has arisen. Take, for instance, the volcanic range of hills east of Honolulu in the Hawaiian Islands. This range runs N.W., S.E. The eastern side bears the full brunt of the trade winds, and it is on this side that nearly all the rainfall of the island occurs; the high mountains wring from the trade wind all its moisture, and consequently as it blows over the western part of the island it assumes the character of a dry wind; the eastern side is therefore intensely eroded, presenting a gigantic cliff which, except at one point in the whole range, is hardly accessible to human foot, while the western side is gently inclined and has the appearance more of a sloping plateau than part of a mountain range. The same action has gone on in the Drakensberg. When the volcanic peaks towered up in a long line running in a north-easterly direction they caught the full blast of the rainy south-easters, which precipitated their moisture on the windward side; on the leeward side the rainfall was slight, consequently the windward slopes of the mountain were eroded at a great rate, while the leeward was gently carved out by the denuding action of running water, and formed an incised plateau, a character which Basutoland still expresses. The windward side, therefore, became steeper and steeper; great falls of rock occurred, which were carried away to sea by the impetuous mountain torrents, and presently the very centres of the volcanoes were exposed, and eventually the progress of erosion continued further till only the northern slopes of the old volcanic pile contributed to form the mountain chain, and the vents, no longer situated in the loftiest portion of the range, got worn down and down till most of them are now found at the lowest levels at the foot of the mountains. Some, however, strengthened by a weather-resisting backbone of solidified lava, held out longer than the rest, and now occupy outstanding positions on the flanks of the mountains, and these form the most interesting ones of the series, as it is in these that one can trace the lava-flows and other surface features.

I will not go into details of all the varieties of vents with the particular rocks that each contains; that information will be embodied in the usual Annual Report of the Geological Commission, but I will take one or two cases from which the general nature of these volcanoes can be understood. One of the best of the agglomerate pipes occurs on a farm, "Deer Park," belonging to a Dutchman named Bekker, who had for a long time speculated on the nature of this peculiar jumble of all sorts of rocks; it is just in front of his house, and forms a very conspicuous object along the road. The pipe is about a quarter of a mile in transverse section, and is

slightly elongated in a N.W., S.E. direction; a river cuts it in two, but on the northern side the bed of the river runs for a short distance between the encasing Stormberg Beds and the pipe, so that the latter stands up like a cylinder on one bank of the river. The variety of rocks in the pipe is astonishing; the ground mass is a white sandy substance very like the ordinary trachyte-tuff that occurs with most volcanoes of a type less basic than these particular ones. The percentage of quartz in the ground-mass is unusually high. In this tuff there are all sorts of varieties of lava: some rounded and vesicular like bombs, others odd-shaped lumps of amygdaloid of every kind of igneous rock that is found in the district, and, in addition, large pieces of sandstone and shales, pieces of rock that have been torn from the sides of the vent and ejected with the other truly volcanic material. The size of the fragments lies between minute lapilli to boulders 3 feet in diameter. The beds adjacent to the present surface of the vent consist of Stormberg sandstone, and are bent downwards and inwards towards the pipe, as if the material in falling back into the vent had dragged the surrounding beds with them. There is a good deal of dolerite in the pipe, probably forming a dyke-like mass, but the surface of the ground where the dolerite occurs is too much covered with *débris* to allow one to make out the relationship of the rock. One very peculiar point about this pipe is that there are a few rare bits of charred wood in the tuff. It seems very curious at first glance to find wood in a volcanic pipe, but one can get a very reasonable explanation if one supposes that before the last outburst there had been a long period of quiescence, and the slopes of the volcano were not only covered with forest, but that trees had actually grown inside the crater. This is by no means an uncommon occurrence in volcanoes at the present day. When then the final eruption took place, some of the trees became dragged down with the rain of falling boulders and ashes, and broken bits of branches became embedded in the tuff.

This last pipe occurs in the river-bed at the foot of the range, at about 5,000 feet above sea-level. If we climb up the mountain we find a sharp-pointed peak standing out from the general line of escarpment (Fig. 1). It looks peculiar owing to the fact that the dolerite with which it is apparently capped is arranged in rough columns, but on getting on to the peak one finds that the dolerite forms a cylinder surrounded by a rim of white Cave Sandstone; at one spot there is a well-characterised mass of agglomerate, consisting of a blue, sandy matrix, with numberless rounded bombs of vesicular lava embedded in it. These features are sufficient to establish the

nature of the hill as being of volcanic origin, but on the north side there is a thin flow of amygdaloidal lava passing from the pipe towards the great mass of lava that forms the mountain-crest behind; the lava-flow was the first that occurred in this region, for it can be traced underlying all the others in the escarpment at the top. This first flow is covered near the vent by two or three others, but at one place the latter have been weathered away, leaving a shelf which shows the actual surface of this first flow. The surface has the peculiar structure known as ropy, and is that which any viscid material acquires when allowed to flow slowly, and can be well seen in pitch that oozes out of a broken barrel. The ropy surface, I take it, is a proof that the lava was poured out on the surface of the ground, and not under the sea as has been suggested, as it is unlikely

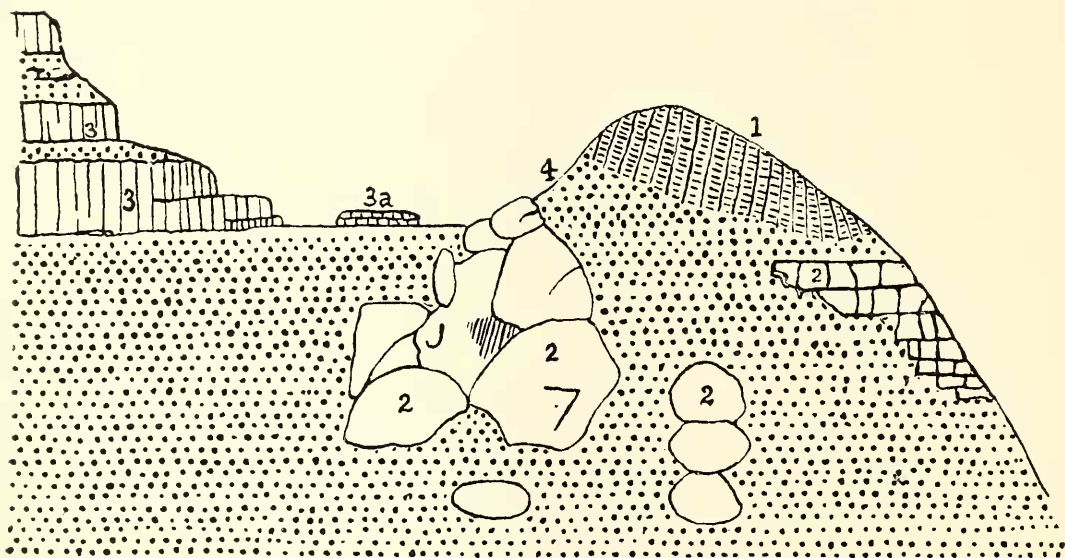


FIG. 1.

View of the high volcano on Deer Park, seen from the west. 1. Plug of columnar dolerite. 2. Cave sandstone forming a rim round the plug. 3. Amygdaloidal melaphyre forming the crest of the Drakensberg. 3a. A portion of a flow of amygdaloid which has evidently come from the vent, and which passes beneath the rest of the lavas on the north; at one place this flow shows the ropy surface of cooled lava. 4. A small tract of volcanic agglomerate with vesicular bombs and fragmental sedimentary rocks. The stipling represents the grass-covered slopes.

that such a structure could be formed under water with considerable pressure to add to the fluidity of the molten rock. The thickness of these three lava-flows that can be seen near the vent are remarkably thin, being only 1 foot to 3 feet in thickness, while there are small flows wedged in between the principal ones that are hardly a foot in thickness.

The main plug of the vent consists of dolerite, which on solidifying has assumed a rough columnar structure, and further each column has split up into a number of wedge-shaped fragments. To the south-east of this volcano there are a number of hills capped with a precisely similar rock, distant from the volcano from 2 to 3 miles. These caps are probably part of one of the early flows, and if so it is one of the few that can be traced flowing southwards. It can be easily seen how this particular flow would withstand denudation, owing to the hard, compact nature of the rock, the ordinary lavas being easily decomposable amygdaloids. The petrographical examination of this lava-flow promises many interesting features.

The ordinary lava is an amygdaloid, and forms the bulk of the crest of the Drakensberg range. It has been described by Professor Cohen * from specimens sent from Basutoland by Mr. J. Orpen. Professor Cohen calls the rock a melaphyre. I have, however, collected an immense number of varieties besides the melaphyre; the latter, though undoubtedly forming the larger proportion of the lava-flows, is interbedded with other types of more acid or more basic type, more crystalline or more glassy, of which I hope a preliminary description will be given in our next Annual Report. The lavas are full of blow-holes, as is usual in other lavas. These arise from the fact that all molten material, as it exists deep down in the earth's crust, is permeated with water-vapour, and owing to the great pressure at these depths the vapour is forced to occupy a very contracted space. When the lava is brought to the surface the same thing happens as when a deep-sea fish is brought to the surface, the water-vapour in the one case, and the air in the air-bladder of the other, expands, and as the fish bursts with the expansion, so the water-vapour forces the rock asunder and produces the cavities. No rock in its natural state is, however, entirely free from water, and this is always slowly creeping about, sucked in through cracks so minute that the highest powers of the microscope fail to reveal them, and even, as there is good reason to believe, through the very inter-molecular spaces of the crystals. Water thus circulating carries with it certain salts in solution, and when it oozes slowly into the cavities of the rock it deposits the salts before being driven out again through the substance of the rock. In this way nearly all the vesicles in ancient lavas are filled in with a group of minerals peculiar to such rocks and called zeolites. Cohen has described the zeolite occurring in his specimens as Heulandite, a hydrated calcium aluminium silicate, but I have not yet been able to determine the varieties in my specimens; besides the zeolites quartz and calcite

* *Neues Jahrbuch*, 1875.

are very common. Ordinarily these amygdules are rounded, but in the Drakensberg a peculiar variety occurs in the shape of long, thin pipes, about the thickness of a lead pencil. These often anastomose and form branched bodies like some of the corals. The pipes stand upright in the flow, and in typical cases there is at the bottom, at the contact with the sandstone or underlying lava, a compact mass which has cooled quickly. Then, half an inch above the lower surface, there is a zone of small vesicles; then, again, a thin layer of compact rock. Above this comes the regular layer of pipe amygdules standing thickly packed together, and averaging 4 or 5 inches in length; sometimes in the thicker flows there is another zone of pipe-amygdules above this first one, and separated from it by a layer of compact rock, but more frequently this second row consists of short pipes or vesicles elongated in a vertical direction; five to eight separate vesicles have been counted arranged above one of the pipes below. Such a prodigious development of large vesicles is not known to occur elsewhere, and points to a great amount of water-vapour held occluded in the molten magma than usually happens; it also points to the sudden eruption of the magma, which did not allow time for the water-vapour to get expelled on the way up from the regions of intense pressure. Agates in the form of pipe-amygdules have been for a long time familiar to the diamond diggers on the Vaal River, where they occur with ordinary rounded agates; they have probably been derived from the disintegration of the Drakensberg and Maluti amygdaloids. Many of the lava-flows, however, do not show this structure, but are filled with rounded vesicles, and others again are compact crystalline rocks, from which the excess of water-vapour was got rid of before extrusion.

Some of the lava-flows immediately above the sandstones are full of pieces of sedimentary rocks, which they have picked up in their course, and held up in their substance when liquid. A good example of this is to be found in Glen Alfred, where the base of the flow is like an agglomerate, so thickly studded are the bits of foreign material.

The two Deer Park volcanoes already mentioned are by no means the only ones on this farm. The general trend of the whole group in Matatiele is 60° E. of N., but the Deer Park volcanoes occupy a line nearly at right angles to this direction, and on the south side of the Drakensberg. I have been able to find altogether six distinct vents in a distance of about three miles, the two referred to above are the largest, the others are very much smaller, and the two ones at the southern end of the line are only 6 and 4 yards across. Possibly there are others, and I strongly suspect that the orchard by

Bekker's house is on a large volcano, since the soil around is particularly poor and sour, but just at this point it seems to be rich; at any rate trees flourish on it. The form of the hills around also leads one to suspect a volcano as they form a steep-sided amphitheatre, on the south of which two small pipes make their appearance. South of Makomereng also there are three volcanoes in a line at right angles to the general trend, and these lie right away from the mountains, and are separated from them by the deep valley of the Kenigha. At Ongeluk's Nek, the place over which Adam Kok came with all his waggons from Griqualand West, and where he smashed most of them up, there is a very large volcanic pipe partly filled in with agglomerate and partly with dolerite, which is in continuity with a heavy flow of that material in a south-easterly direction. The volcano is beautifully dissected by a tributary of the Mabele River, and a new road has been cut right through it, so that very perfect sections in a fresh state are available for study. On the west side of the volcano there is a bed of agglomerate wedged in between the sandstones, showing that the shower of ashes spread over the country far and wide. The particular spot was probably a lake, and when the agglomerate had been deposited the ordinary sedimentation followed and covered the agglomerate with sand. This is the only instance of such a bed that I found in Matatiele, but Dunn states that they are common round Jamestown and Molteno.

The amygdaloidal lavas at Ongeluk's Nek contain very large amygdules of quartz, calcite, and zeolites, and many of the flows have covered up soil and sediment that formed in previous flows. The soil now presents a crumbly, earthy appearance, and the sediments, formed either along the sides of the runnels that carried away the storm-water of the volcano, or in temporary lakes caused by the damming up of such runnels by cross flows of lavas, have been baked and hardened to such an extent that some of the shaly beds have been actually porcellanised. One bed is particularly interesting, showing that the greatest change is not along the sides of the bed, where it was in contact with the molten lava, but in the centre. This porcellanised shale was thought to be gold quartz, and it, and the larger amygdules were actively prospected not long ago, but with no results, though gold is reported to have been found in minute quantities.

At the bottom of the Ongeluk's Nek pass the amygdaloids descend to the level of the plain, so that they are much more available for study than at other places where they are high up on the mountain-side; beautiful examples are here afforded of ropy surface, and of sections showing the lavas filling in the inequalities on the surface

of the older lavas which had been produced by erosion during a period of rest from volcanic activity. Here also three thin dykes of dolerite cross each other at a particular point, and they can be traced for many miles running each in a straight direction through the horizontal beds of amygdaloid.

Between George Moshesh's country and Makomereng there is a larger dyke of dolerite which thickens out to an enormous mass in Maklagala's country and thins out gradually on either side. The direction of the great dyke is not quite parallel to the present line of the Drakensberg crest, but approximates more nearly to the general direction of the line of volcanoes. Sections showing the relationship of the dolerite to the amygdaloid are not frequent, but on Makomereng there are some which show the dolerite cutting through the lower beds of lava, and then bending over and covering these as a thin sheet, which again is covered with more amygdaloids.

I was not able to determine finally whether the dolerite was only intrusive between the amygdaloids or had been poured out on the surface and then covered with more vesicular lavas. I am strongly inclined to believe that the latter was the case, both from the appearance of the rocks in section, and also since the dyke in some places is curiously mixed up with the encasing wall, and appears to have arisen explosively in the crack; in another place the amygdaloidal lavas seem to be in continuity with the dolerite of the fissure. It is very doubtful, also, whether such an immense body of molten rock could come so near the surface as this one did without pouring out some of its material. It is an interesting point which I hope the petrographical examination of the rocks will be able to clear up, for if it proves to be a true fissure of eruption we have a splendid example of a phenomenon which has been surmised to exist from theoretical considerations, but never yet actually found to exist.

South of this there is a smaller dyke which has also the appearance of having arisen explosively in its crack, for it includes many fragments of the wall of the dyke included in the substance; the igneous rock and the north wall is intensely crumpled and injected with small dykes, and these phenomena are unknown in the ordinary dykes of the district. Further west again, near Rankakata's Nek, there is another great dyke with the lava apparently pouring over the surface of the sandstone, but the surface features have been too much eroded to allow of any definite statement to be made as to the nature of the fissure.

Before going into the consideration of these volcanoes in regard to their tectonic aspect, I should like to mention the Cave Sandstone which has puzzled me exceedingly. It is a soft granular sandstone,

creamy to brilliantly white. It forms thick massive beds often 60 to 100 feet thick, and weathers in extraordinary pepper-pot and mushroom shapes, or again in immense tabular masses. It sometimes contains structures that look like plant stems, and cavities also in it are filled in with chalcedonic silica, like in the agates and opals of the lavas that lie upon it. It always accompanies the volcanoes, and is especially thick in their neighbourhood, whereas in the east of the district where the volcano line crosses over the Drakensberg Mountains into Basutoland, the Cave Sandstone is absent for some distance south of the Drakensberg, and the lavas rest directly on the Red Beds. The whole appearance of the rock is so strikingly similar to a trachyte tuff, that I at first took it to be such, and thought that it was the result of the first explosive outbursts of the volcanoes, which were situated at that time beneath the sea, but microscopic examination shows it to be made of quartz and felspar, the latter largely microcline, but, except in one doubtful case, I have found no volcanic glass, and no mica or other ferro-magnesium constituent. Mr. Lewis, of the Government Analytical Laboratory, has analysed it for the Geological Commission, and his analysis finally settles that it is a sedimentary rock and not a tuff.

The group of volcanoes just described taken together are arranged along a line trending roughly 60° E. of N.; if the western end is produced it will run through the three volcanoes discovered by Mr. Dunn near Jamestown and Molteno. Whether there are volcanic vents in between these two groups, and whether they occur along this line it is impossible to say until the survey of Barkly West and Herschel is undertaken, but from the description of the country, and from what we know of the occurrence of volcanoes elsewhere, I think most geologists would say that there could be very little doubt on the matter.* If we accept the view that there is a whole series of volcanoes arranged along a line of weakness in a direction about 60° E. of N., we have a weapon for attacking some very difficult problems in the past history of South Africa—problems which have a bearing on the structure of the continent as a whole.

I am afraid this line of reasoning is somewhat complicated, not that it involves obscure points, but as each step forms a problem in itself, and as nothing has yet been published on the matter, each step wants a great deal of discussion before it can be accepted as proven. First of all it is essential to understand the river system of South Africa. This consists of two quite distinct series, an old

* Mr. Dunn in a map made to accompany the same report, G4, 1878, but never published, shows two more volcanoes to the east of Jamestown, namely, Glat Kopjes and Wonderbosch Klip.

and a comparatively new one. The old one was started before the eruption of the Drakensberg volcanoes, and was developed on a comparatively featureless plain. It consisted of a number of rivers having their sources along a straight line which ran through the country in a direction roughly 60° E. of N. From this watershed, which can still be clearly traced from the Cape Peninsula to Delagoa Bay, a distance of about 1,000 miles, the waters flowed on one side in a south-easterly direction and on the other in a north-westerly one. The watershed now is only once cut through by the Orange River. After this principal river system was developed stresses in the earth's crust forced the strata round the coast into folds whereby the main mountain ranges of South Africa were formed, but all this went on so slowly that the old rivers were able to cut their way through the folds as quickly as the ground rose across their courses,

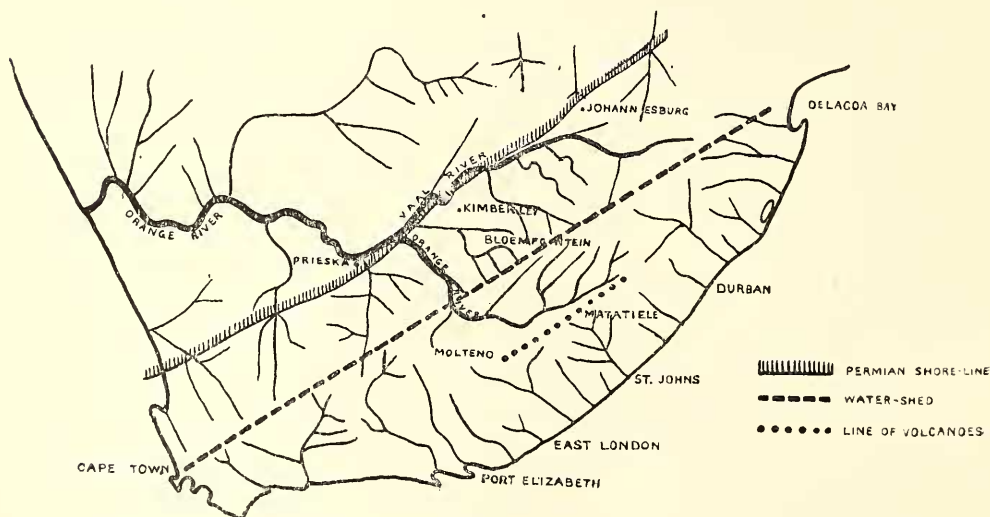


FIG. 2.

Map of South Africa showing the relation of the rivers to the water-shed and the line of volcanoes. It also shows the parallelism between the probable course of the Permian shore-line, the water-shed, the line of volcanoes, and the present shore-line on the south-east of the continent.

and for this reason we get the extraordinary gorges that traverse all the mountain ranges in the south-west of the Colony. When the mountains were formed the old simple drainage system was naturally disturbed, and a new one was instituted to accommodate the new order of things, and in this way we get the two systems, a new one superimposed on an old one. Looking now at the area in which the volcanoes occur (Fig. 2) one notices that the rivers on the north-west side of the watershed arise in exactly the same manner as those on other parts of the same watershed. On

the south-east side the rivers are crowded together, and their arrangement is quite different from any other group of principal rivers in South Africa; they bear evidence of having been deflected from their natural course, which was to the south-east, and having been forced to flow across their natural water-parting. The case of the Caledon River, which flows practically on the watershed, is particularly interesting. I think the map showing the courses of the rivers affords very satisfactory evidence of the volcanic range having been thrown across the primitive river system, which means that the volcanic outbursts occurred after that system had been developed, and that the new land of the Karroo, formed off the shores of the old continent, was already dry land at the time. We know from evidence we can get from the Western Province that this river system was instituted in Jurassic times, so here we have a link in the chain of proof that these volcanoes were Upper Jurassic or Cretaceous.

The second step deals with the deposition of the sediment from the Dwyka Conglomerate upwards, and for this we only have a knowledge of the distribution of a small part of the Cape Colony, and a still less complete knowledge of the distribution in the Transvaal. The Dwyka Conglomerate in the Colony is a deposit containing glaciated or scratched boulders of a number of peculiar types, all of which have now been traced to their origin in the north-west of the Colony, Bechuanaland, and the Transvaal. From which it follows that the glaciers which carried these boulders flowed from the north-west. Mr. Rogers and myself have found in the Colony the actual beds of these glaciers, and have seen the old land-surface over which they flowed. The course of the glaciers was to the south, between S.S.W. and S.S.E., and the old shore-line ran through Prieska in a direction about N.E., passing west of Johannesburg and near Mafeking. Dr. Molengraaff, in Vrijheid in the Eastern Transvaal, has found a similar land-surface, over which the ice moved in a north-westerly direction, so here we have evidence of two shore-lines, separated by the width of the Transvaal, which in Permian times was occupied by an inland sea.*

In the south of the Colony the Dwyka was not deposited on a land-surface, but the mud was laid down under water and the boulders dropped into it from the floating ice that broke off the ends of the glaciers. In this way we are able to get an idea of the trend of

* The conglomerate in Natal, to the east of the Vryheid occurrence, was also probably formed on land, which leads one to suspect that the country from which the Vryheid glaciers flowed was an island.

the old shore-line of the continent that existed in Permian times, which afforded the sediments for the Dwyka Conglomerate and succeeding strata.

It is interesting at this stage to notice the change of sediment that resulted from the degradation of this old continent from the times when it rose in mighty mountains towering above the snow-line, although so near the Equator, and glaciers, with their peculiar morainal matter, crept down their sides; through times when, in the course of ages, the effects of weathering had cut the mountains down so that snow no longer accumulated on them, and the climate of the continent became more genial, the rivers discharged sediments which now form the Eccra shales, characterised by abundance of vegetable life; to the time when the continent became hot and the Karroo reptiles multiplied on the land, and sediments peculiar to shores off tropical lands were deposited.

The third step depends on what becomes of the sediments deposited off the shores of continents. It is by no means universally accepted, but the view is every day gaining in favour that the crust sinks under the weight of accumulated sediments, and certainly we have the fact that the sediments from the Dwyka Conglomerate to the Upper Karroo are bent into a basin-shaped form: this can only have happened by the crust bending; but the question whether this is due to surface being weighted by the sediments or to some other cause I will not now enter upon, but for the sake of brevity I will take it that the crust did sink under the weight. The sediments from the old north-western continent went on accumulating; sinking allowed a vast amount of material to be deposited, but finally the sea became very shallow. It was about this time that the great dykes and sheets of dolerite were intruded into the Karroo Beds, and the sediments, up to the Upper Karroo, were lifted above the surface of the water and became dry land. It was on this new land that the first river system was developed as explained previously. The new land formed a fringe of some 100–150 miles broad running parallel to the old shore-line.

We come now to the question of the Stormberg Beds, which were deposited outside this new land. Are the Stormberg Beds made up of sediments such as we should expect from the degradation of a land formed in the manner we have just described? The sediments from such a land would consist entirely of very fine detrital material, as it is itself entirely formed of fine *débris* from the waste of the old continent.

The Stormberg Beds are certainly formed close in shore. The muds which occur in the series are full of the most perfect remains

of fossil ferns which could not have floated far before they became embedded, but the softer beds are separated at repeated intervals by great beds of coarse sandstone. This sandstone is what Mr. Dunn calls "glittering sandstone," and seen in the strong sunlight it has the appearance of having every grain specially faceted to catch and reflect the light. The grains consist of clear fresh quartz, such as one gets in granite or felsite, often as big as peas, and sometimes showing unworn crystal faces; besides quartz there is a very large amount of felspar, now weathered and turned into kaolin, but many grains still retaining sharp crystal faces, and in addition large mica flakes are frequently found. These sandstones must have been derived from a granite or quartz-felsite, and not a dyke of such material is present in the Karroo, and again, the grains of quartz, felspar, and mica are too fresh to have travelled all the way from the old northern land. The Karroo land in Jurassic times then could not have afforded the material for the Stormberg Beds. Whence, then, was the material derived? The only answer is, from a land-mass to the south which has since sunk beneath the sea. From other considerations derived from the study of the western part of the Colony we had already begun to believe that an old land-mass had once existed along our southern shores, but we had no very safe arguments to go upon; but taking all the evidence now it is highly probable that in Cretaceous times there existed a large archipelago of islands, if not a connected land-mass, in the neighbourhood of our present southern shores; and that it was in the sea, enclosed between this southern land and the old northern land that the sediments from the Table Mountain Sandstone upwards were deposited. It is very probable that Madagascar and the Seychelles are remnants of this southern continent, but off our present shores the sea-bottom shows no trace of the presence of a submerged land.

Let us now see how all this bears on our volcanoes. First of all there was a shore-line running roughly N.E. Sediments were deposited off the shore of this continent in a band parallel to it, that is, also N.E. A watershed afterwards was formed in these new sediments running N.E. A line of volcanoes broke out, that line running N.E., and the shore of our present land was cut off in a N.E. direction. I think few people would deny that all these phenomena had some common cause which gave the dominant trend to all.

My explanation is as follows:—The sediments from the Dwyka Conglomerate upwards were deposited on an inland sea,* the centre

* It should be noted that this is not the same inland sea that Mr. Dunn postulated in his paper to this Society (*Trans.*, vol. xi., pt. 1, pl. i.), since where he

of which ran in a N.E. direction, parallel to the old southern land surface, and it was here that the greatest depth of sedimentation occurred. The crust sank under the extra weight in doing so, the underlying beds became strained, and eventually lines of weakness were produced which allowed the molten material beneath the solid crust to force its way upwards in the form of dykes and sheets of dolerite. The sediments thereby became intensely heated, expanded, and tended to decrease their curvature, hence the whole mass rose, sediments and injected dolerite together. The line of greatest deposition, and consequent most intense heating, had the greatest relative elevation, hence on emerging from the water the flat lands of the Karroo already had a very well-marked water-parting to begin with, and this is the watershed that still dominates the river system to-day. Where the dolerite had not been injected the strata remained stationary, and on the hinge of the movement a further weakness was produced, and that hinge would be situated in the position where we now find the volcanoes. There are dykes of dolerite in the Stormberg Beds, but there is very good reason to believe that they are of a later date than the central Karroo ones. Given a line of weakness in the earth's crust, there needs no explanation to understand how volcanoes become formed along it.

Such are some of the points raised by the discovery of these new volcanoes, and though much may have to be altered later, when the survey of the Colony progresses and new material accumulates and the survey of Natal and Eastern Transvaal is brought into line with our work, yet I have thought it well to bring the points before the Society at this early date because they form an entirely new departure in the way of regarding the structure of our continent and have an important bearing on some of the theories of the origin of continental areas in general.

places his southern shore line, along the flanks of the Zwarteberg range, the sediments show no signs of being shore-deposits, and to the south of the mountain-belt, near Worcester, there are occurrences of Dwyka Conglomerate and Ecca Beds that must have once been continuous with those on the north of the mountains, and these also are deep water-deposits. The inland sea that I am referring to must have had its shore line to the south of our present coast.